MARS 2001 SCIENCE OPPORTUNITIES

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This paper describes the status of the planned NASA Mars Surveyor Program 2001 orbiter and lander. If the lander is approved for launch, it will be sent to a safe landing site. The site selection process has identified a region of hematite that is level, relatively rock-free and scientifically exciting because it may represent the site of an ancient lake once filled with iron-bearing water. The water has long since evaporated, but may have left behind an enormous deposit of iron oxide. Such, deposits occur on Earth and can seal in evidence of ancient life in a secure mineral envelope. The orbiter is expected to launch on schedule in early 2001. It carries the gamma ray spectrometer, a thermal emission spectrometer (THEMIS) and imager that will map the mineral abundance at selected sites and a radiation experiment, Marie, to assess radiation hazards to humans. The lander payload includes a robotic arm with camera. The arm will deploy a Moessbauer spectrometer to determine the state of iron in the soil, an especially important measurement at the hematite site. The arm will deploy the rover and dig up to 0.5 m to deliver soil to MECA, the soil and dust characterization experiments. The Mars In Situ Propellant Precursor Experiment (MIP) will produce oxygen from the Martian atmosphere. The Marie radiation experiment will assess radiation hazards on the surface. The panoramic camera is bore-sighted with a thermal emission spectrometer to examine mineralogy. The descent imager (MARDI) will image from parachute deployment to the surface. The rover is Sojourner class, with an upgraded Alpha Proton X-ray Spectrometer (APXS) experiment calibrated on Earth and on Mars. The 2001 lander carries the first elements in the combined Mars strategy of the Human Exploration and Development of Space (HEDS) and Space Science Enterprises of NASA.

Mars 2001 Science Opportunities

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JPL

Mars Exploration

NASA

The Common Thread

W A T E R

When
Where
Form
Amount

The Common Thread	Primary Goals		Resulting Knowledge
WATER	**LIFE**	Evidence of Life: Past or Present	Understand the Potential for Life Elsewhere in the Universe
WATER	**CLIMATE**	Weather Processes & History	Understand the Relationship to Earth's Climate Change Processes
When / Where / Form / Amount	**RESOURCES**	Environment & Utilization	Understand the Solid Planet: How It Evolved and Its Resources for Future Exploration

JPL

Science Objectives

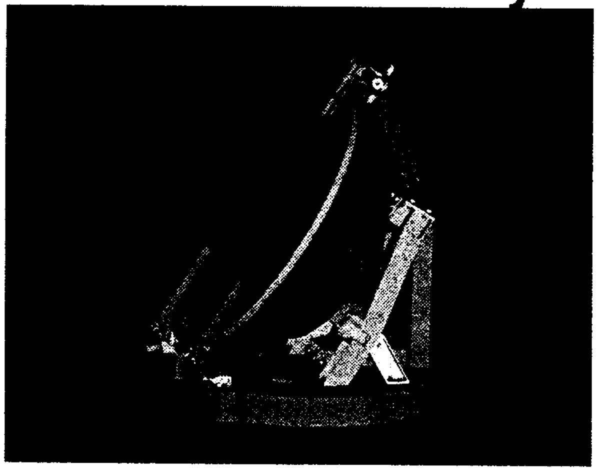
- Globally map the elemental composition of the Martian surface, and determine the abundance of hydrogen in the shallow subsurface
- Acquire high spatial and spectral resolution maps of surface mineralogy
- Acquire high spatial resolution images of surface morphology
- Provide "nested" high spatial resolution descent imaging of the landing site
- Determine the nature of local surface geologic processes from surface morphology
- Determine the spatial distribution and composition of surface minerals, rocks, and soils surrounding the landing site. Extend this knowledge to the surrounding region by correlating orbital with lander and rover data.
- Characterize the Martian surface radiation environment as related to radiation-induced risk to human explorers; characterize specific aspects of the mars near-space radiation environment that will complement measurements made on the Martian surface.
- Characterize the Martian soil and dust, including physical properties, oxidation properties, and chemical and mineralogical properties.
- Assess, through in situ experimentation, the feasibility of producing useable propellants from the indigenous Martian atmosphere.

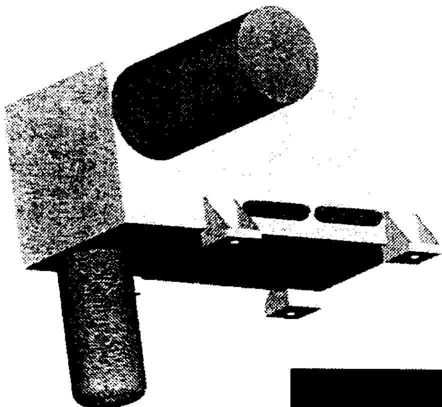
Payload Assignments

- The Mars Surveyor Program 2001 Payload Is Assigned to the Flight System Elements as Follows:
  - The orbiter science payload shall consist of:
    - Gamma Ray Spectrometer (GRS)
    - Thermal Emission Imaging System (THEMIS)
    - Mars Radiation Environment Experiment (MARIE)
  - The lander science payload shall consist of:
    - Elements of: Athena Precursor Experiment (APEX)
    - Mars Descent Imager (MARDI)
    - Mars Radiation Environment Experiment (MARIE)
    - Mars Environmental Compatibility Assessment (MECA)
    - Mars ISPP (In-situ Propellant Production) Precursor (MIP)
  - The rover science payload shall consist of:
    - Alpha/Proton/X-ray Spectrometer (APXS) - Part of APEX
    - Imaging Sensor System (ISS)

Gamma-Ray Spectrometer (GRS)

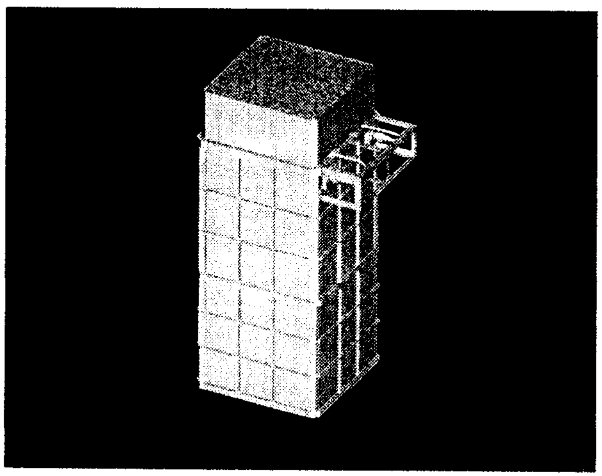
Gamma Sensor Head





High Energy Neutron Detector

Neutron Spectrometer



OBJECTIVES: Full planet mapping of elemental abundance with an accuracy of 10% or better and a spatial resolution of about 300 km, by remote gamma-ray spectroscopy, and full planet mapping of the hydrogen (with depth of water inferred) and CO2 abundances by remote neutron spectroscopy

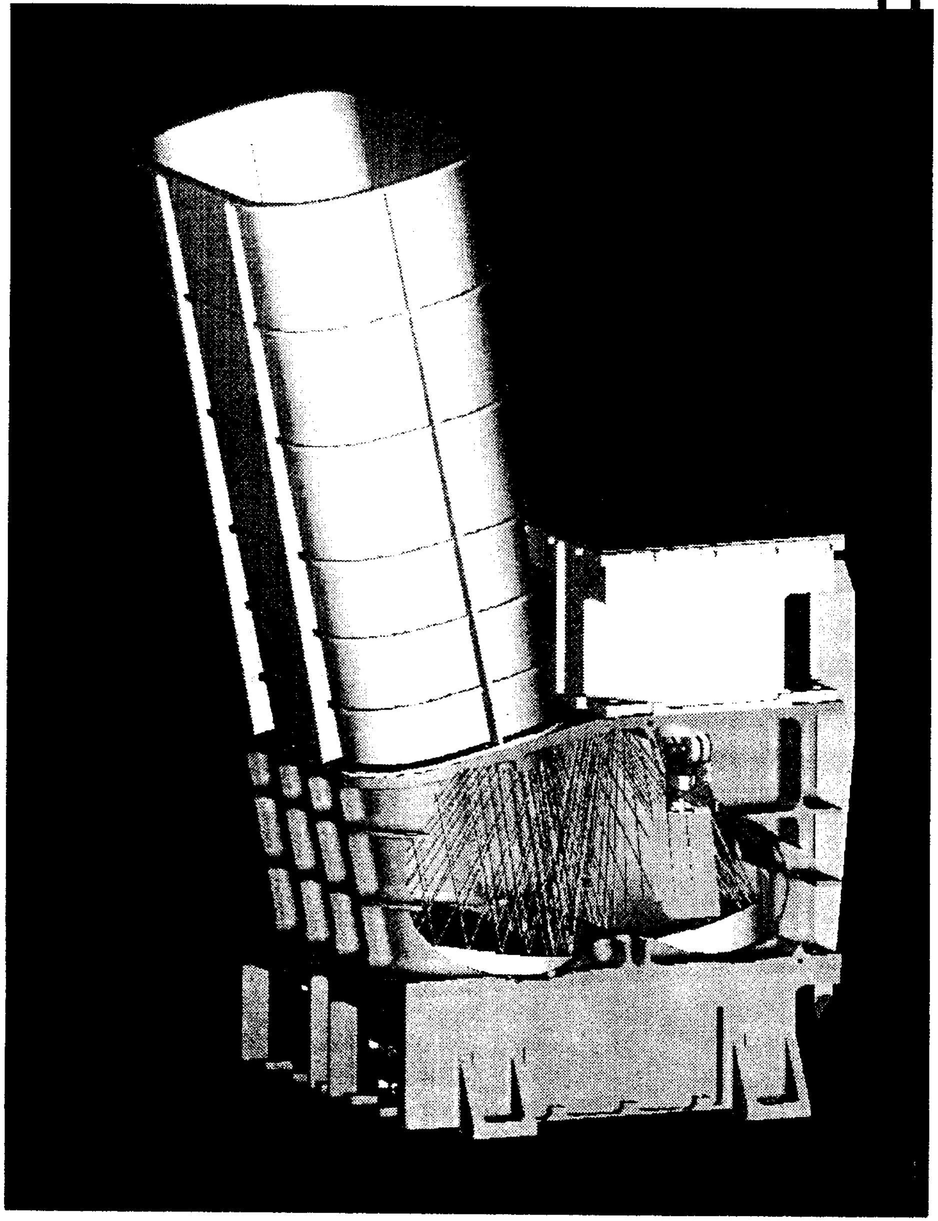
SCIENCE TEAM: PI is William Boynton. Co-I's are James Arnold, Peter Englert, William Feldman, Albert Metzger, Steve Squyres, Jacob Trombka, Heinrich Waenke, (Claude d'Uston-TBD). HEND PI is Igor Mitrofanov.

SUPPLIERS: U of Arizona, LANL, A.D. Little, Eurisys Measures (France), and IKI (Russian Space Research Institute). Hop Bailey is Instr. Mgr.

HARDWARE: GRS sensor head with 85 K cooler, neutron spectrometer (NS), & high energy neutron detector (HEND). Cooler FOV = 170˚. Energy range is 0.2 to 16 MeV. CPU = 386.

INTERFACE: Mass = 30.1 kg. Power = 27.6 W. Volume = 48 dia. x 26 cm gamma sensor head, 13 x 13 x 29 cm NS, 27 x 22 x 19.2 cm HEND. Data rate = 2.5kbsp. 100˚C annealing. 6 m boom. S/C materials usage requirements

Thermal Emission Imaging System (THEMIS)



OBJECTIVES: Determine the mineralogical composition of the surface for minerals whose abundance is approximately 10% or greater and at spatial scales of approximately 100 m. Provide information on the morphology of the surface such that features significantly less than 100 m can be adequately resolved.

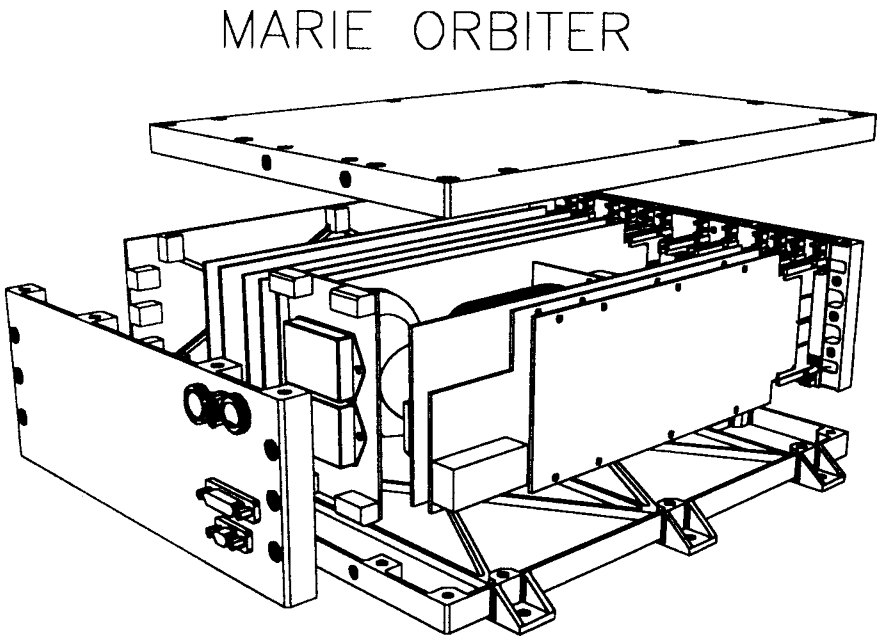
SCIENCE TEAM: PI is Philip Christensen (ASU). Co-I's are Bruce Jakosky, Hugh Kieffer, Mike Malin, Harry McSween, and Kenneth Nealson.

SUPPLIERS: Arizona State U, SBRS, MSSS. Greg Mehall is the Instrument Manager.

HARDWARE: Multi-spectral IR image, visible imager (M98 heritage), 3 mirror, 20 cm focal length, f/1.7 anastigmat telescope, 4.6° (along track) by 3.5° (downtrack) IR FOV, 2.9° x 2.9° Vis FOV. Resolution = 80 m (IR) and 20 m (VIS). Spectral Range = 6.5 to 15.5μ (IR) and 0.425 to 0.8 μ (Vis). Detectors are 320 x 240 pixels (IR) & 1024 x 1024 pixels (VIS).

INTERFACE: Mass = 12.8 kg. Power = 14 W. Volume = 55.8L x 37.9H x 28.0W cm. Uses 2 high speed RS-422 data lines.

Martian Radiation Environment Experiment (MARIE)



OBJECTIVES: Orbiter MARIE - Characterize specific aspects of near-space radiation environment, characterize the surface radiation environment as related to radiation-induced risk to human exploration, and determine and model effects of the atmosphere in an attempt to predict anticipated doses and assess its radiobiological effectiveness.

SCIENCE TEAM: PI is Gautam Badhwar (JSC).

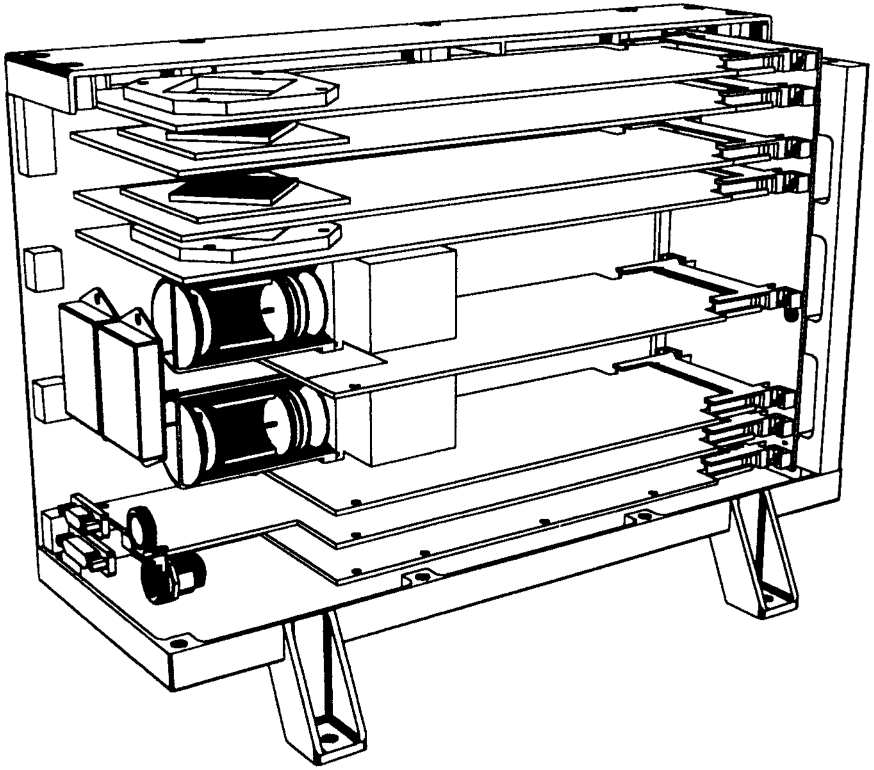
SUPPLIERS: JSC. Robert Dunn is the Instrument Manager. Subcontractors are Lockheed Martin and Battelle Pacific Northwest.

HARDWARE: Energetic particle spectrometer, 56° FOV, 2 silicon detectors 25.4 x 25.4 mm, 120 MB flash memory, Intel processor. Measures SEP events from 15 to 500 MeV/nucleon.

INTERFACE: Mass = 4.0 kg. Power = 7 W. Volume = 10.8H x 29.4L x 23.2Wcm. Data rate is 3 Mbits per day over RS-422 low speed data line.

Martian Radiation Environment Experiment (MARIE)

MARIE LANDER



OBJECTIVES: Lander MARIE - Measure the accumulated absorbed dose and dose rate in tissue as a function of time, determine the radiation quality factor, determine the energy deposition spectrum from 0.3 keV/µm to 1000 keV/µm, and separate the contribution of proton, neutrons, and HZE particles to these quantities.

SCIENCE TEAM: PI is Gautam Badhwar (JSC).

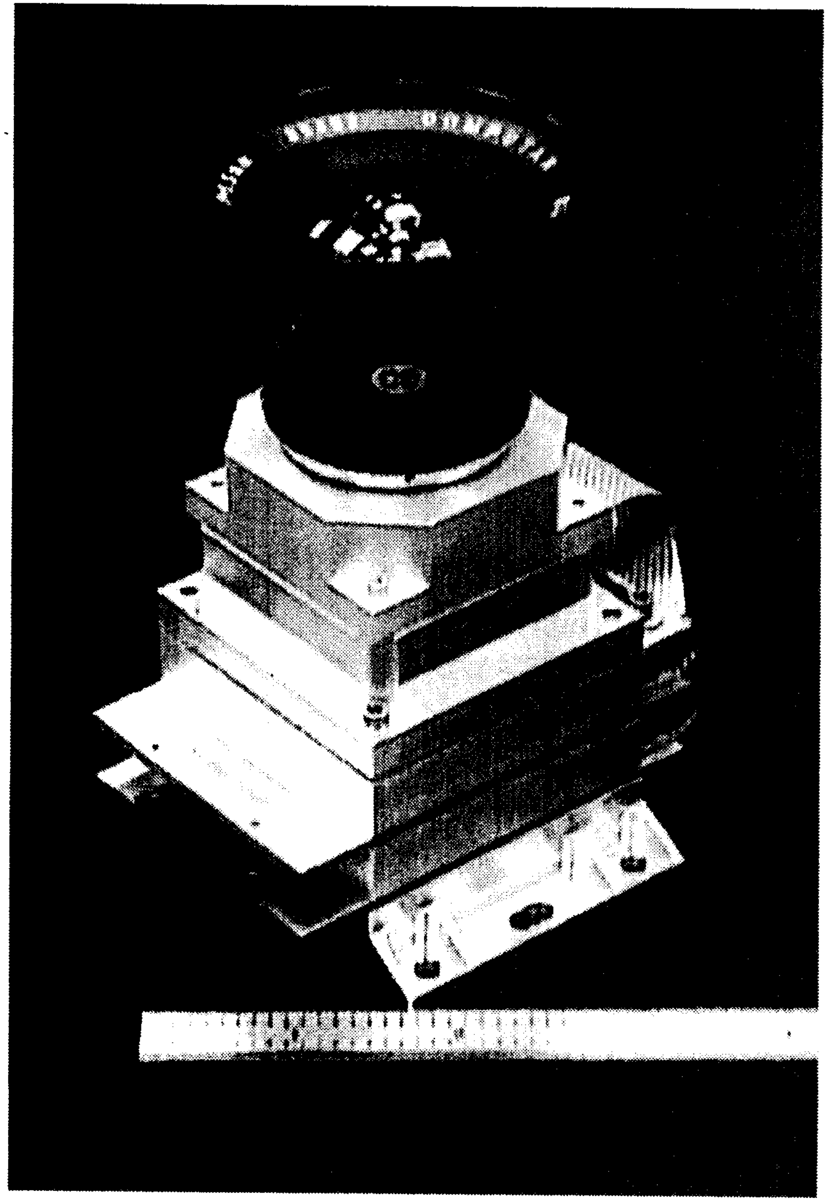
SUPPLIERS: JSC. Robert Dunn is the Instrument Manager. Subcontractors are Lockheed Martin and Battelle Pacific Northwest.

HARDWARE: Energetic particle spectrometer with two 24 x 24 position sensitive detectors followed by 2 proportional counters 1.78 dia x 1.78 cm (TEPC & CPC), 56° FOV, 60 MB of flash memory, and an Intel processor. Measures the linear energy transfer range of 0.3 to 1000 keV/µm in 512 channels.

INTERFACE: Mass = 4.0 kg. Power = 6.8 W. Volume = 15.8W x 34.3L x 23.7H cm. Data rate is <8 Mbits per day over RS-422 low speed data line. Contains 2 - 0.9 µCurie alpha sources and 2 - 40 torr propane vessels (proportional counters).

JPL

Mars Descent Imager (MARDI)



OBJECTIVES: Characterize the geology of the landing site and provide geologic context for collected samples. Determine the nature of local surface geologic processes from surface morphology, and provide a link between local and regional geologic processes, and provide images (>20) for nearby Rover traverses.

SCIENCE TEAM: Team Leader is Mike Malin (MSSS). Team Member is Ken Herkenhoff.

SUPPLIERS: MSSS and TBD optics supplier. Mike Ravine is the Instrument Manager.

HARDWARE: This is a M98 build to print MARDI - Panchromatic camera, 9 element f/2 optics, focal length of 7.135 cm, 73.4° FOV, 500 to 800 μ spectral range, resolution of 12.5 cm/pixel @ 100 alt., 5:1 nesting, using 1024 x 1024 pixel CCD @ 8 bits/pixel with compression of <2:1. Processor is Motorola DSP56166 @ 30 MIPS.

INTERFACE: Mass = 0.52 kg. Power = 5W. Volume = 8 x 8 x 12.7 cm. Utilizes a high speed RS-422 data line and the S/C computer for data processing.

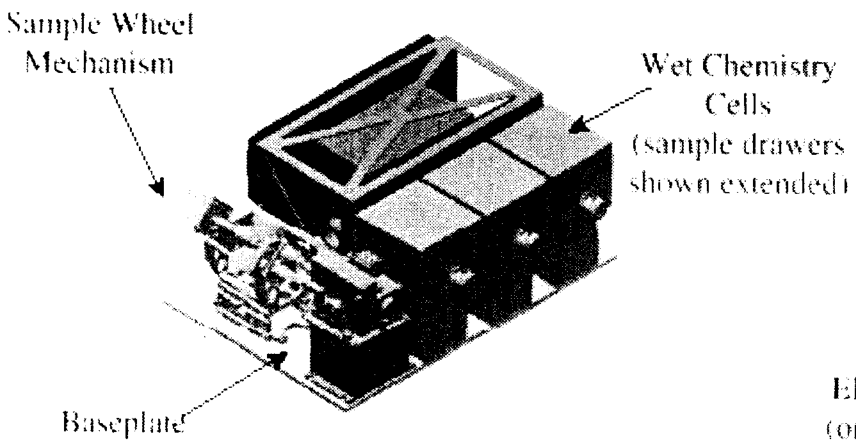
Mars Environmental Compatibility Assessment

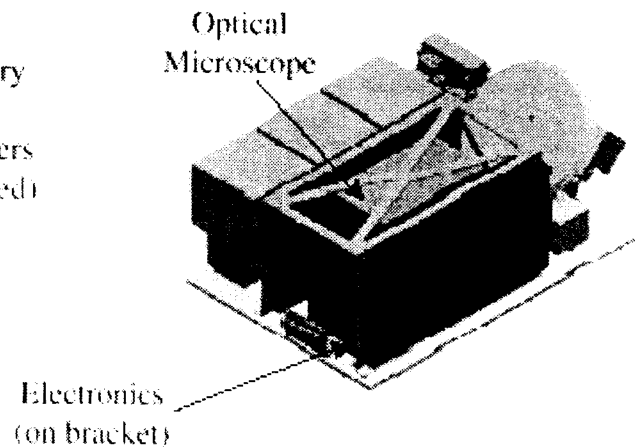
M ***icroscopy Station:*** Optical and Atomic Force Microscopes image mineral and rock grains, measure morphology, hardness, magnetic and electrostatic properties.

E ***lectrometer:*** Monitors electrical field and triboelectric charging during robot arm operation.

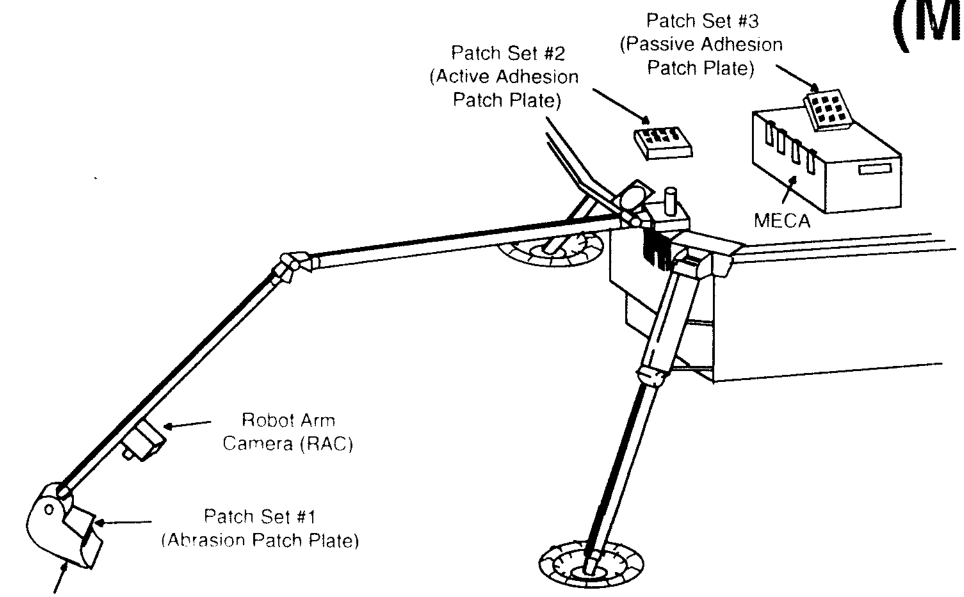
C ***hemistry Laboratory:*** Sensors analyze pH, redox, conductivity, and dissolved salts in soil-water mixture.

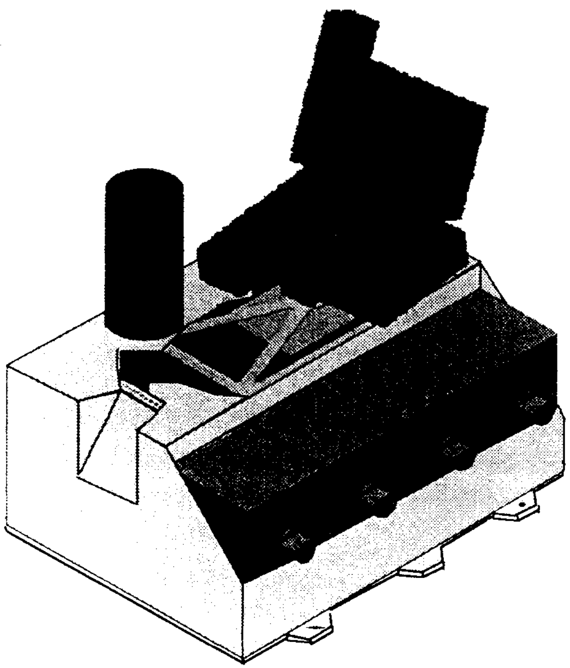
A ***dhesion/Abrasion Plates:*** Camera images allow investigators to evaluate degradation of materials.





Mars Environmental Compatibility Assessment (MECA)





OBJECTIVES: Characterize dust and soil (size, shape, adhesion, and abrasion), identify undesirable and harmful interactions with human explorers and associated hardware systems, and support the design of extravehicular activities & habitation systems.

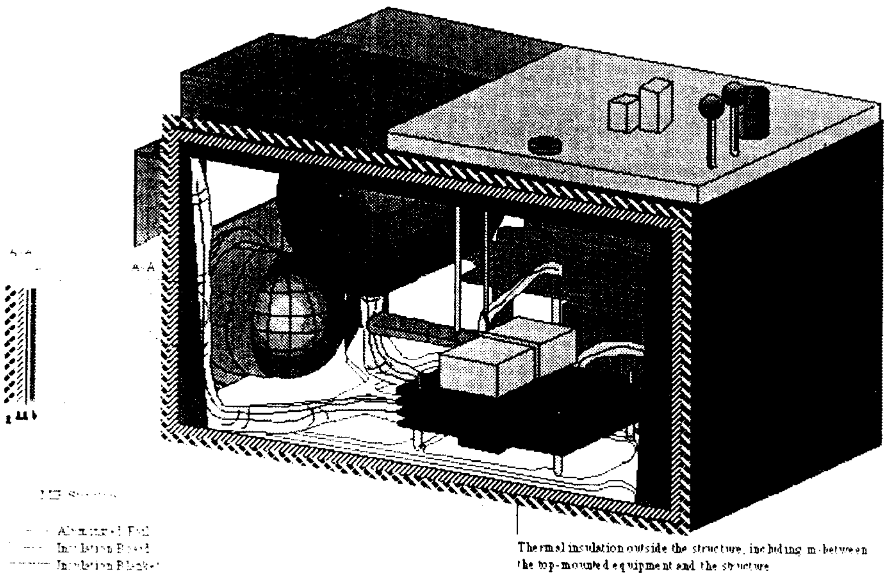
SCIENCE TEAM: PI is Thomas Meloy (W. Virginia U). Co-I's are Michael Hecht, Mark Anderson, Steve Fuerstenau, Thomas Pike, Wayne Schubert, Martin Frant, Peter Smith, Horst Uwe Keller, Wojtek Markiewicz, John Marshall, Calvin Quate

SUPPLIERS: JPL, Max Planck, U of Arizona, and Stanford. Michael Hecht is the Instrument Mgr. Joel Rademacher is the System Engineer.

HARDWARE: 4 integrated instruments = Atomic force microscope, optical microscope, electrometer and a wet chemistry laboratory. Also includes a sample wheel and 3 patch plates.

INTERFACE: Mass = 10 kg. Power = 5 W. Volume = 27W x 37L x 15H cm deployed, plus patch plate and Mössbauer target mounted on top. Uses 1 RS-422 low speed data lines. Needs the robotic arm for soil samples, the robotic arm camera, and the camera's redundant electronics.

Mars ISPP Precursor (MIP)



Preliminary MIP Configuration and Thermal Design Concept

OBJECTIVES: Demonstrate operation of critical in-situ propellant production (ISPP) subsystems and process in the Mars environment. Characterize aspects of the Mars surface environment which will impact ISPP operations.

MIP TEAM: PI @ JSC is Dave Kaplan. Jim Ratliff is the instrument manager.

SUPPLIERS: JSC, JPL, LeRC, & Lockheed Martin. Jim Ratliff is the instrument manager.

HARDWARE: MIP includes 5 integrated instruments:

- DART - Dust Accumulation and Removal Test
- MAAC - Mars Atmosphere Acquisition and Compression
- MATE - Mars Array Technology Experiment
- MTERC - Mars Thermal Environment/Radiator Characterization
- OGS - Oxygen Generating Subsystem

INTERFACE: Mass = 8.5 kg. Peak Power is 15W. Power Night is 3W. Volume = 45.4L x 25.4W x 31.1H cm. Desires 140° FOV (+Z) for the MTERC and DART.

MIP Experiments

MIP will incorporate five experiments from three NASA institutions; Johnson Space Center (JSC), Lewis Research Center (LeRC), and the Jet Propulsion Laboratory (JPL). JSC is also responsible for integrating the experiments into the MIP flight demonstration unit

The five MIP experiments are:

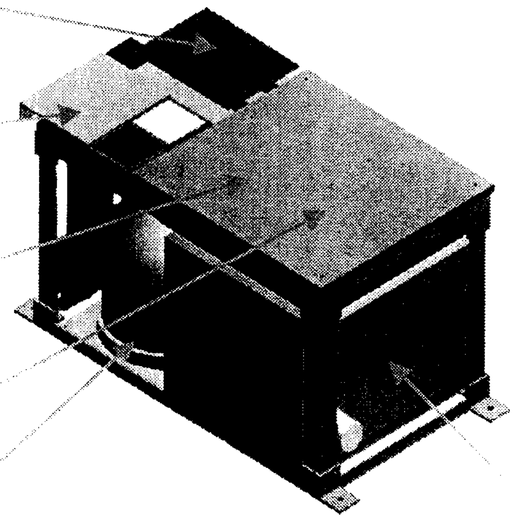
- **MAAC - Mars Atmosphere Acquisition and Compression (JPL)** Demonstrate the ability to collect and compress Mars atmospheric carbon dioxide

- **Mars Thermal Environment and Radiator Characterization (JPL)** Provide data to determine the effective sky temperature and the long term effect of the Mars environment on radiator performance

- **Technology Experiment (LeRC)** Characterize advanced solar cell performance and obtain data on Mars surface environments that can impact future solar cell designs

- **Accumulation and Repulsion Test (LeRC)** Demonstrate techniques to mitigate dust accumulation on solar cells (tilting and electrostatic repulsion) and characterize dust properties and deposition rates

- **Generator Subsystem (JSC)** Demonstrate the production of oxygen from Mars atmospheric gases in the Mars environment

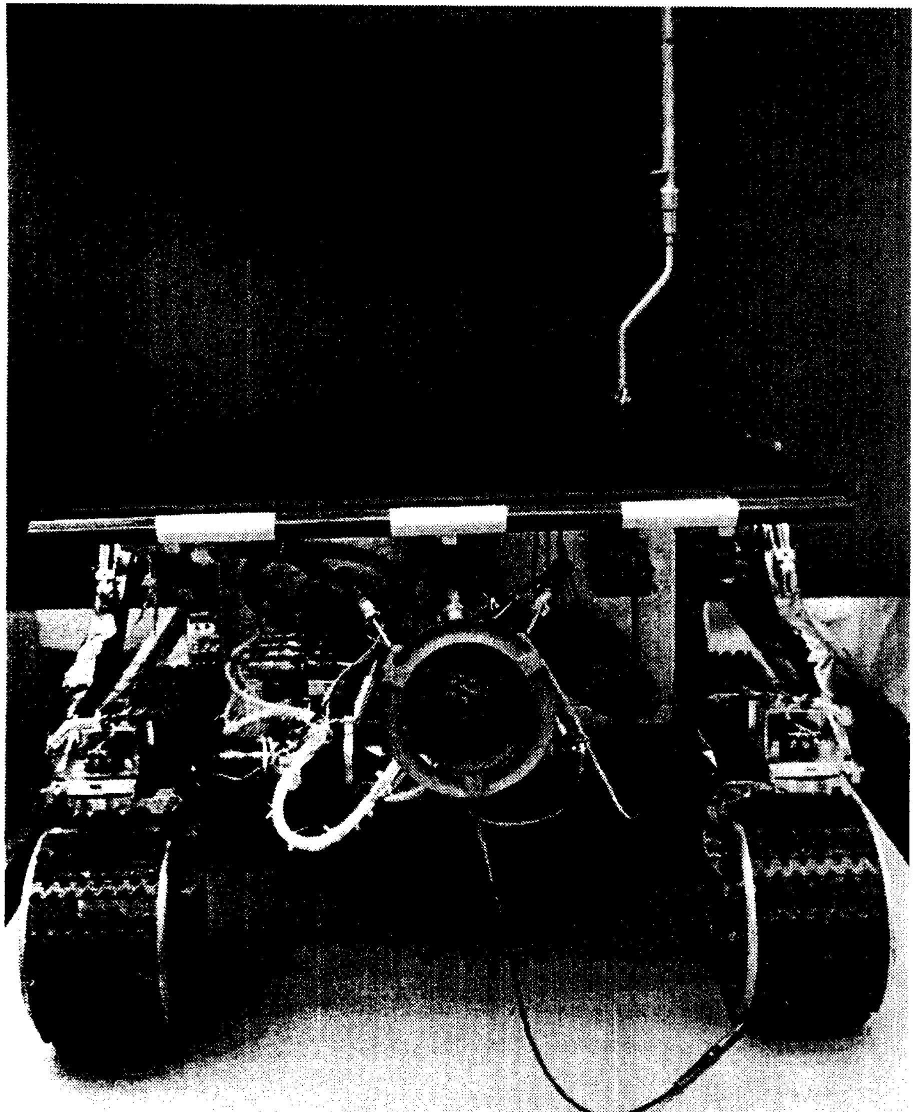


MIP Design Characteristics

- **Mission Design Life = 300 Mars days (sols)**
- **Mass = 8.5 kg**
- **Dimensions = 40 cm L x 24 cm W x 25cm H**
- **Average Power; Day = 16 Watts*, Night = 3 Watts**

* When producing oxygen; 9 Watts average without oxygen production

ROVER - MARIE CURIE with APEX APXS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- OBJECTIVES: The APEX Alpha Proton X-ray Spectrometer (mounted on the Rover) will determine elemental chemistry of surface materials for most major elements except hydrogen. The approach used is to expose material to a radioactive source that produces alpha particles with a known energy, and to acquire energy spectra of the alpha particles, protons and X-Rays returned from the sample.

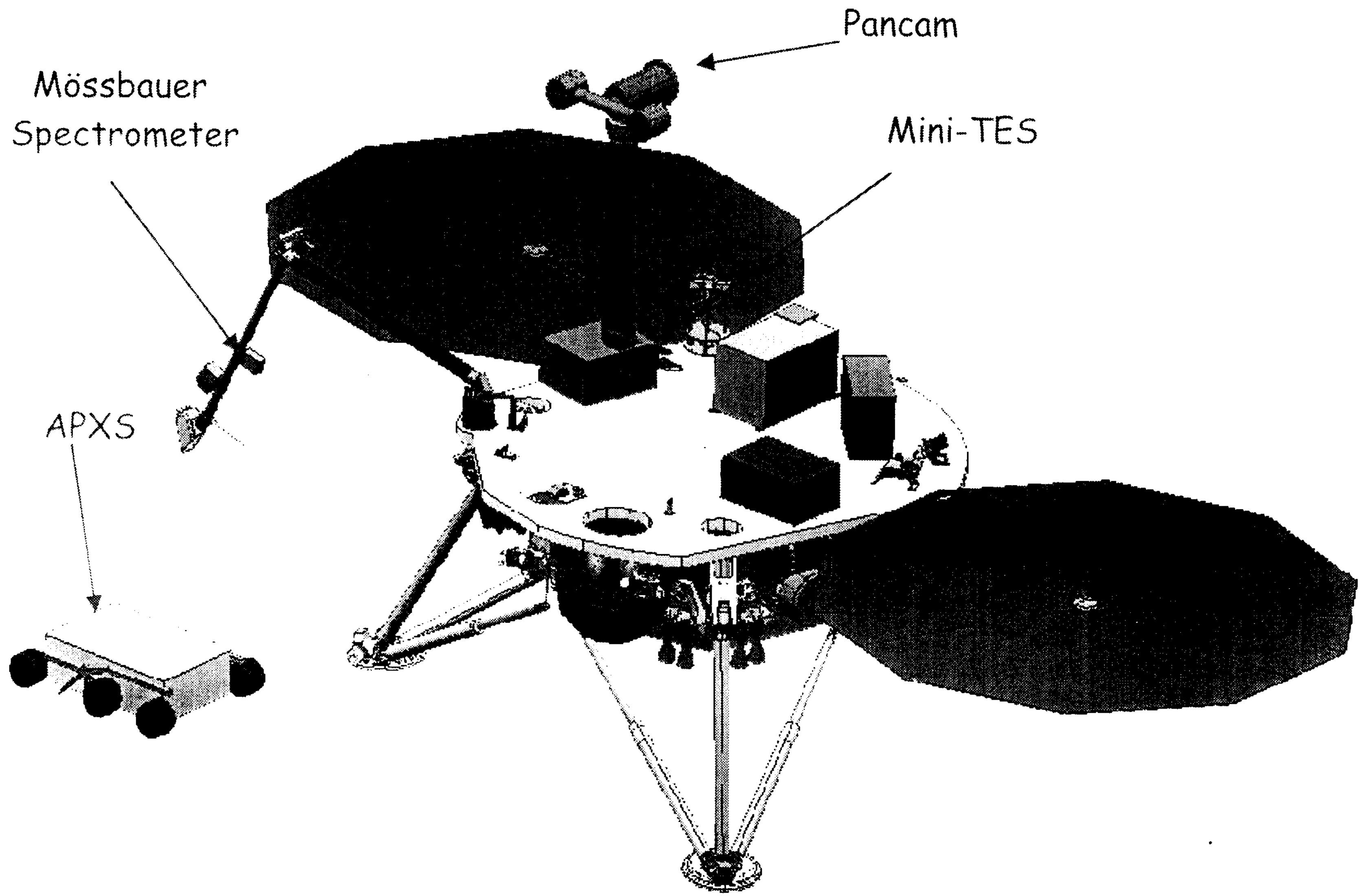
- SCIENCE TEAM: I - Steven Squyres (Cornell). Co-I's are R. Arvidson, J. Bell, M. Carr, P. Christensen, D. Des Marais, T. Economou, S. Gorevan, L. Haskin, K. Herkenhoff, G. Klingelh`fer, A. Knoll, J. Knudsen, M. Malin, H. McSween, R. Morris, R. Rieder, M. Sims, L. Soderblom, H. W‰nke, T. Wdowiak. Barry Goldstein is the Project Manager.

- HARDWARE: This elemental composition instrument consists of alpha particle sources and detectors for back-scattered alpha particles, protons and X-Rays. The APXS sensor head is mounted external to the Rover chassis on a deployment mechanism. This mechanism places the APXS incontact with rock and soil surfaces. The APXS electronics are mounted within the rover, in a temperature-controlled environment. Mass = 16.0 kg

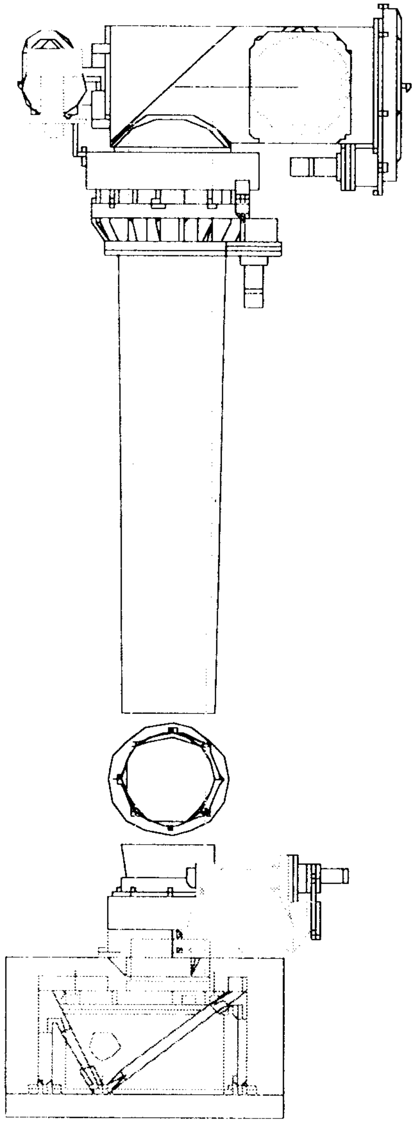
ATHENA Precursor Experiment

- The *APEX Lander Instrument Suite* is four scientific instruments and their associated hardware
- The instruments:
  - — *Pancam:* A high-resolution stereo multispectral panoramic imager.
  - — *Mini-TES:* A mid-infrared spectrometer for remote determination of rock and soil mineralogy
  - — *Mössbauer Spectrometer:* An *in-situ* instrument for determination of mineralogy of Fe-bearing rocks and soils
  - — *Alpha-Proton-X-Ray Spectrometer:* An *in-situ* instrument for determination of elemental chemistry of rocks and soils
- Associated hardware:
  - — *Calibration targets* for all four instruments
  - — *Magnet array* to accumulate atmospheric dust and be viewed by the Mössbauer Spectrometer
  - — *Interface electronics*
  - — *Mini-TES thermal enclosure*

APEX Element Locations



APEX - PanCam/Mini-TES & Mössbauer Spectrometer



PanCam & Mini-TES

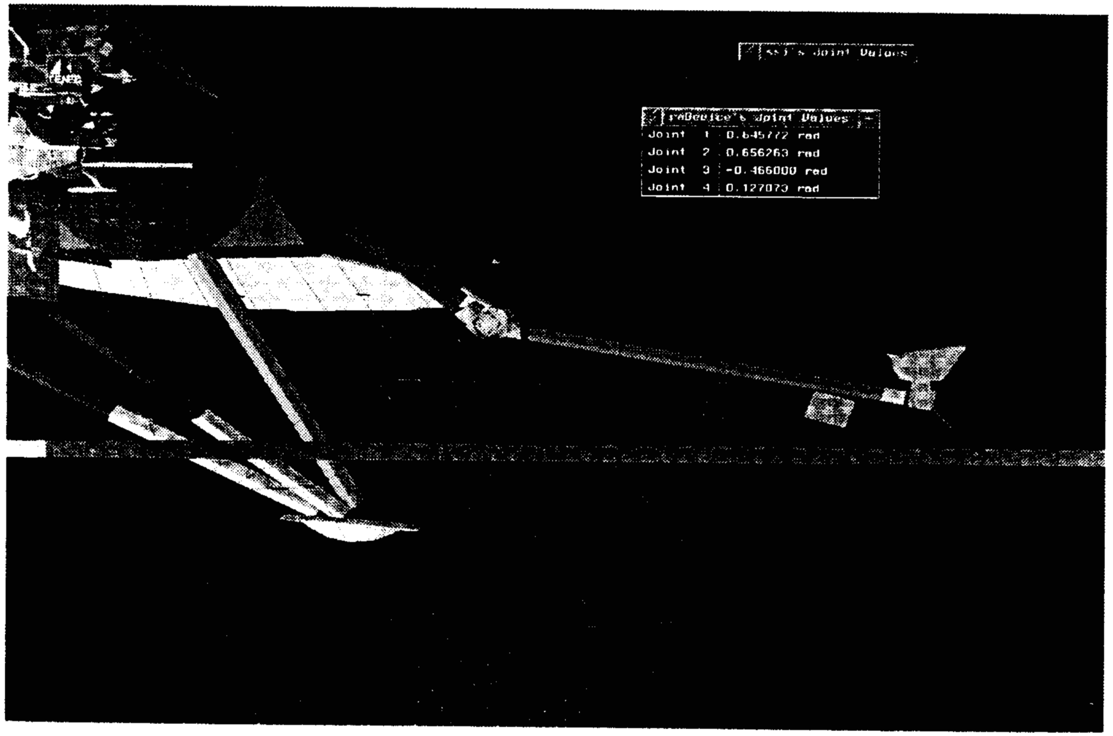
OBJECTIVES: Assess the geologic history, climatic history, and biological potential of the landing site, provide high-resolution color stereo images of the scene around the lander, determine the mineralogy of rocks and soils around the lander, & determine the mineralogy of the magnetic portion of martian dust.

SCIENCE TEAM: I - Steven Squyres (Cornell). Co-I's are R. Arvidson, J. Bell, M. Carr, P. Christensen, D. Des Marais, T. Economou, S. Gorevan, L. Haskin, K. Herkenhoff, G. Klingelhˆfer, A. Knoll, J. Knudsen, M. Malin, H. McSween, R. Morris, R. Rieder, M. Sims, L. Soderblom, H. W‰nke, T. Wdowiak. Barry Goldstein is the Project Manager.

HARDWARE: Includes an infrared spectrometer with spectral range of 5-40 µm, a stereo multispectral imager (0.4 to 1 µm) with an angular resolution of 0.28 mrad/pixel, and a Mössbauer Spectrometer on the Robotic Arm with magnet target. The APXS is part of APEX but located on the Rover. Also supplies Payload Electronics Box (PEB) for Lander instruments.

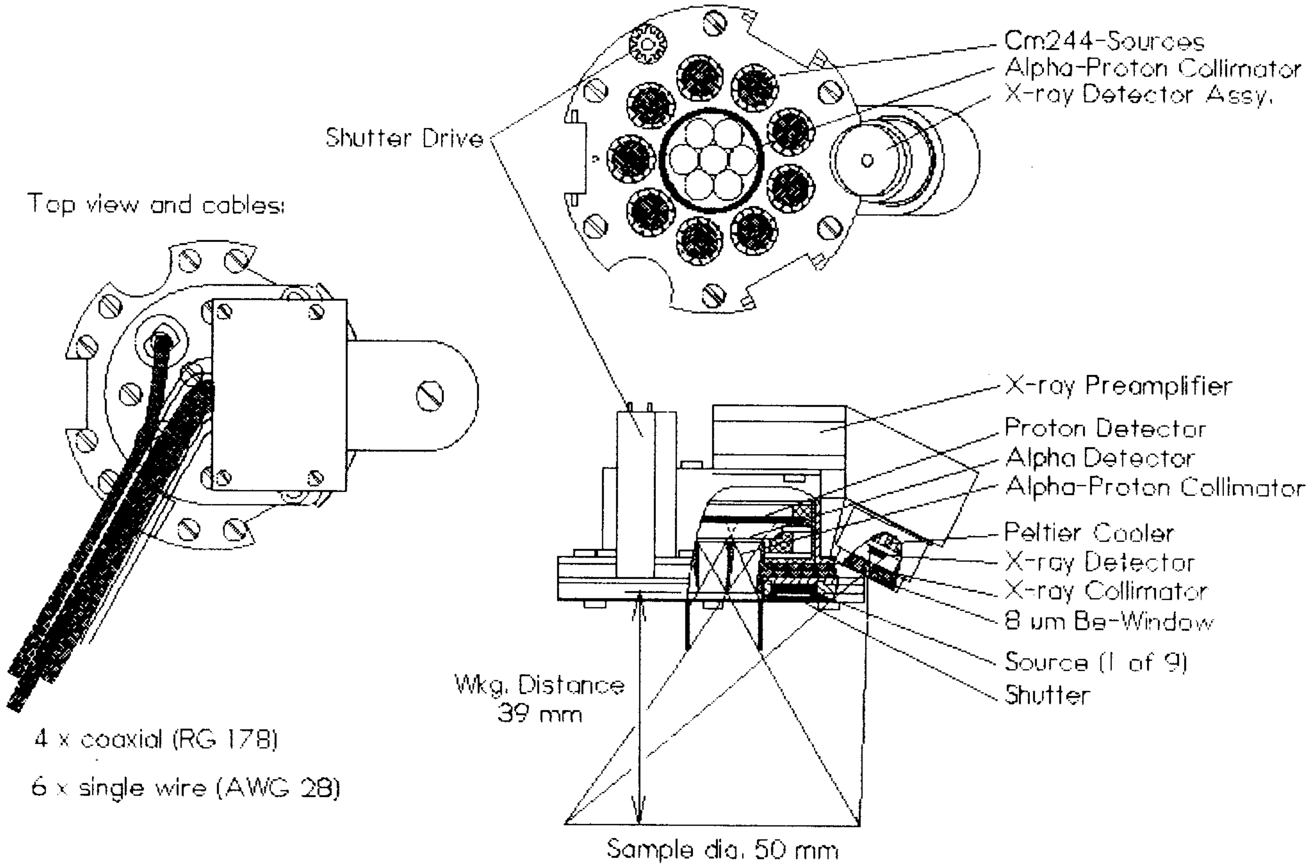
INTERFACE: Mass = 18.5 kg. Needs 2 high speed and 2 low speed RS-422 data lines. Uses lander CPU and software. Includes targets for PanCam, Mini-TES, and Mössbauer.

Mössbauer Deployment

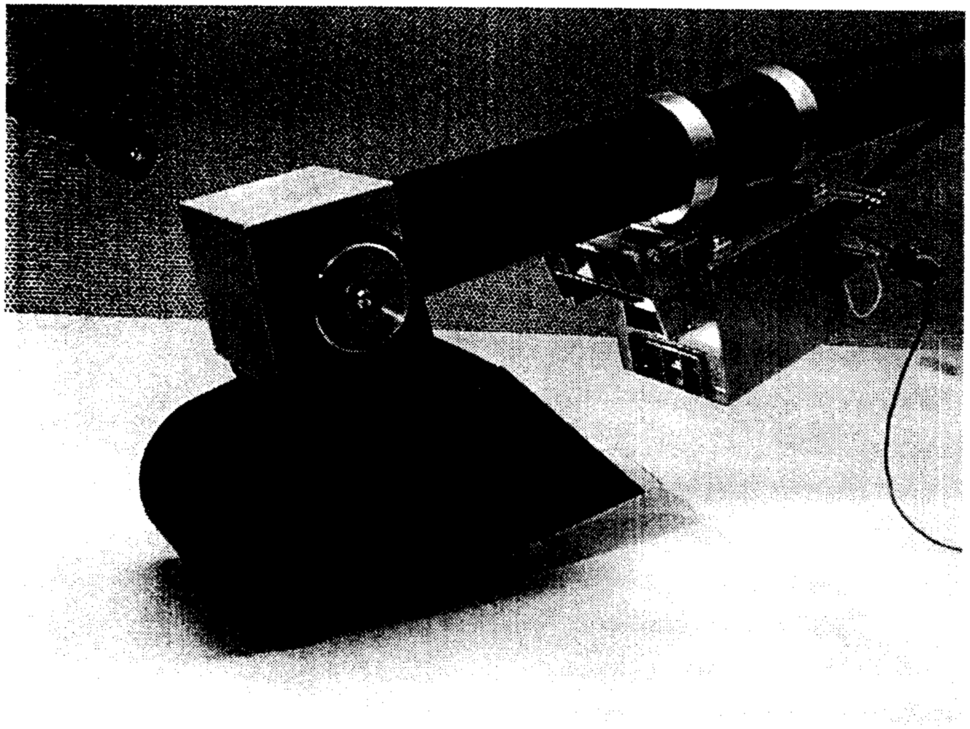


- Mössbauer shown here on MSP'98 Robotic Arm
- Contact geometry limited by elbow flex angle and by thermal probe/rover hook contact with soil
- Action on '01 Robotic Arm team to try to increase flexure by ~10°
- Martian surface material can also be "piled up" using arm

APXS Background-Reduction Collimator



Robotic Arm Camera (RAC)



OBJECTIVES: Imaging support for the MECA patch plates, Rover deployment, RA digging, and obtaining MECA soil samples.

RAC TEAM: Project Manager is Peter Smith. Robert Reynolds is the instrument manager.

SUPPLIERS: University of Arizona and Max Planck Institute (MPI).

HARDWARE: Camera head supplied by MPI. FOV is 25° x 50° at infinity. Active focus with 12.5 mm focal length lens @ f/12. Focus range for objects at distances from 11 mm to infinity. On board leds provide red/green/blue illumination. Exposure times from 0.5 to 32 seconds, with a 2 second readout time. Electronics, located in the payload electronics box (PEB), also provide support to the MECA microscopic imager. Uses512 x 256 pixel frame transfer CCD with 23 micron pixel spacing. Camera head and electronics are largely M98 build to print.

INTERFACE: Mass = 1.83 kg. Camera head mounts near end of robotic arm.

2001 Rover Mission Objectives

- Contribute to the scientific exploration of the '01 landing site through:
  - calibration of the APXS on Mars
  - imaging soil and rocks using rover cameras
  - acquire APXS measurements of soil and rock to establish groundtruth for PanCam / MiniTES

- Contribute to future operations development by establishing:
  - rover control interface to MSOP / LMA
  - integrated rover control and imaging toolsets for rapid image processing
  - interface between distributed science planning and operations
  - as a goal, use lander based PanCam images to update rover position knowledge
  - as a goal, traverse back to a specified location near the lander to demonstrate a sample return maneuver.

- Contribute to education and public outreach:
  - Planetary society / science team cooperation which involve students in mission